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Engineering Design File

Leachate Generation Study

Idaho National Engineering and Environmental Laboratory

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ENGINEERING DESIGN FILE

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The U.S. Department of Energy (DOE) authorized a remedial design/remedial action for the Idaho National Engineering and Environmental Laboratory (INEEL) including the Idaho Nuclear Technology and Engineering Center (INTEC) in accordance with the Waste Area Group (WAG) 3 Operable Unit (OU) 3-13 Record of Decision (ROD). The ROD requires that contaminated surface soils be removed and disposed of on-Site in the INEEL CERCLA Disposal Facility (ICDF). Infrastructure associated with the landfill includes an evaporation pond system and a leachate collection system. This Engineering Design File (EDF) provides the design calculations and assumptions for modeling of leachate generation within the landfill.

A computer model, the U.S. Army Corps of Engineers' Hydraulic Evaluation of Landfill Performance (HELP), version 3.07, was used to determine leachate generation. Modeling was based on performance specification design requirements and applicable climatological (precipitation and evaporation) data. Leachate generation was computed for two operation scenarios: Cell 1 of ICDF open for active waste placement, and Cell 2 open for active waste placement with Cell 1 closed, in order to determine which would produce the "worst-case" leachate production scenario as input to the design of the leachate collection system.

Leachate production was examined for worst-case precipitation and leachate production, as well as average precipitation and leachate production. Results from the computer model HELP for the ICDF landfill for a period of the 10 wettest years at INEEL (consistent with SoilCover fate and transport modeling) indicate that peak daily leachate produced would be 21.0 gallons per minute (gpm). However, more typical ranges lie between 0.0 gpm and 1.8 gpm for the Cell 1 open scenario. Peak daily leachate produced would be 21.1 gpm with more typical ranges and between 0.0 gpm and 1.9 gpm for the Cell 2 open scenario. Predicted maximum buildup of leachate head on the liner is 0.99 in. for Cell 1 and 1.49 in. for Cell 2, far less than the performance criterion of 1 ft, under the assumed conditions. Therefore, the Cell 2 scenario was selected as the controlling condition for design of the leachate collection system and evaporation pond.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer		Dean Bose/ CH2M HILL	Dean H. Bose	05/14/02
Checker	R	(Same as Independent Peer Reviewer)		05/14/02
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ABSTRACT

A widely used computer model developed by the U.S. Army Corps of Engineers, Hydraulic Evaluation of Landfill Performance, was used to determine leachate generation from the INEEL CERCLA Disposal Facility landfill. Modeling was based on performance specification design requirements and applicable climatological (precipitation and evaporation) data. Leachate generation was determined for two operation scenarios: Cell 1 open for active waste placement, and Cell 2 open for active waste placement with Cell 1 closed.

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TABLES

ACRONYMS

ALR	Action Leakage Rate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
DOE	Department of Energy
EDF	Engineering Design File
EPA	Environmental Protection Agency
FS	factor of safety
HDPE	high-density polyethylene
HELP	Hydraulic Evaluation of Landfill Performance
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LDS	leak detection system
NOAA	National Oceanic and Atmospheric Administration
OU	operable unit
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
TAN	Test Area North
WAG	Waste Area Group

Leachate Generation Study

1. PURPOSE/OBJECTIVE

Leachate from the ICDF landfill will be managed using evaporation ponds. The design of the facility is such that leachate formed in the ICDF will be conveyed to an evaporation pond system that consists of twin lined (with Resource Conservation and Recovery Act [RCRA] Subtitle C equivalent liners) ponds where contaminant residue or sludge will precipitate from the liquid as it evaporates. The purpose of this study was to estimate the amount of leachate that would be generated during operation of the ICDF on an annual basis. The estimate can then be used for sizing the leachate ponds and the leachate collection and transmission system. Consideration of potential variation in leachate generation amounts is needed to ensure that the ponds will be adequately sized to handle average and peak flow conditions.

The period of operation for the evaporation pond system includes the 15-year (estimated) active life of the ICDF cell, as well as the 30-year post-closure operating time period. The active life of the pond system represents the period in the landfill life during which maximum leachate can be expected. This is when the landfill is open (prior to placement of final cover) and is actively receiving waste in its two-cell life cycle. The post-closure period of the landfill will be designed to minimize leachate by placement of a final cover over the waste mass. Other Engineering Design Files (EDFs) have been prepared to discuss the performance of the final cover (as referenced below)—the final cover is not considered for this leachate generation study. During the post-closure time period, the leachate ponds will be available to handle the minor quantities of leachate that would be generated from drain-out of the pore space of the waste mass. A conservative approach is desired for estimating leachate generation volumes to ensure that ponds are conservatively sized for handling a variety of inflow conditions.

Computer modeling has made it possible to integrate many input data, such as precipitation, temperature, and solar radiation, into a single model when predicting leachate generation. One such program, widely used for modeling landfill leachate generation, is the Hydraulic Evaluation of Landfill Performance (HELP) model developed by the U.S. Army Corp of Engineers, or HELP. This program was selected for the "Leachate Generation Study" (EDF-ER-280) because it is the most robust modeling package available with the versatility to model a multi-layer liner system like the design of the ICDF. The HELP model is considered to be a conservative model in that it looks at development of steady-state, saturated flow through the various layers of the landfill cross-section. In an arid region such as the INEEL, saturated flow may not always be an accurate representation of leachate flow, due to the limited precipitation and high evapotranspiration of water from materials exposed to the elements. However, conservative estimates are desired for predicting leachate volumes for system component sizing, and the HELP model has been found to provide an adequately conservative design basis for predicting landfill leachate generation and liner leakage estimates in a variety of climates.

1.1 HELP and SoilCover: Consistency in Data

The HELP model used for leachate generation and leakage estimation is different than the SoilCover model used in evaluating the performance of the final soil cover (see "Hydrologic Modeling of Final Cover," [EDF-ER-279], for a detailed discussion of the SoilCover model and the final cover evaluation results). The SoilCover model was used for estimating seepage flow through the final cover as it is a more rigorous and accurate model of unsaturated flow that occurs through a store and release cover system, such as that proposed for the ICDF. However, both models utilize similar data input for precipitation, temperature, and solar radiation that is used in calculation of flow estimates through the system components. For consistency, similar data sets were used for evaluation of both leachate generation and cover performance, as discussed below. The key difference between the two models is that

SoilCover only includes the landfill cover and provides as accurate estimates of water movement as possible, while HELP models the entire landfill, including drainage, waste, and barrier layers, and provides a conservative estimate of leachate production for designing the leachate handling systems.

In order to develop as accurate an estimate as possible within the HELP model, a 10-year time frame was selected for analysis from which actual site data was used for the input parameters of precipitation, temperature, and solar radiation. This time period, from 1967 to 1977, was the same period as that selected for the SoilCover evaluation, to simulate a wet-cycle 10-year average. That is, a wet-cycle 10-year time period was selected from the entire data record available from the National Oceanic and Atmospheric Administration (NOAA) station at the INEEL. Input data for these parameters were developed from the same data set for both the HELP and SoilCover models.

1.2 Operating Conditions: Two Models Examined

Leachate generation was determined for two distinct operation periods at ICDF, Cell 1 operation, and Cell 2 operation, consistent with "Hydrologic Modeling of Final Cover," (EDF-ER-279). Cell 1 operation is defined, for a conservative estimate of leachate production, as the period of operation where Cell 1 of the ICDF is open with one lift (10 ft) of waste in place. Cell 2 operation is defined as the period of operation where Cell 1 is closed and capped with an interim cover (2 ft of native alluvium) and Cell 2 is open with one lift of waste in place. In each case, the model was run for a 10-year period of the wettest precipitation years (see Section 2 for further explanation of input data set). The purpose of modeling two operation scenarios was to provide input for different conditions that might be encountered at ICDF to determine which is the worst-case, and to examine the carryover into the sizing of the evaporation pond for each of these scenarios.

Modeling these two scenarios required running five separate cross-sectional areas of the landfill in HELP, as HELP can only model one vertical cross-section at a time and each condition has multiple cross-section configurations. To successfully model the Cell 1 operation, for instance, it was necessary to consider the bottom of the landfill, at 2.5% slope as well as the side slopes, which have 33% (3:1) slopes. To make this possible, two separate model runs were performed; one for the landfill bottom and one for the side slopes.

A waste surface slope for HELP model runs was based on an estimate of the slope of the waste profile, around 2% in the case of the active operation (HELP Run #1 and Run #3 in Appendix A), except for the side slopes where the model was run with no waste in place. For the closed Cell 1 (HELP Run #5) the slope of the 2-foot-thick interim cover over waste was taken as 2% for the model. The preliminary design for the landfill final cover is 7%; however, the final cover was not considered to be in-place as part of the active operation for the landfill. Run-off from the surface slopes was not allowed as part of HELP Runs 1 through 4, (i.e., all of the precipitation was required to either evapotranspirate or infiltrate). For Cell 2 operation, runoff was only considered for the portion of the landfill with Cell 1 closed with an interim cover (Run #5) and not the active portions of the landfill. A summary of the HELP runs that comprise each cell operation scenario is presented below:

Cell 1 Model HELP Runs (Actual model runs in Appendix A) include the following:

- Run #1: Active Bottom of Cell 1, 2.5% slope bottom slope, 2% waste surface slope (with no runoff allowed)

- Run #2: Open Side slopes of Cell 1, 33.0% slope, bottom and surface (with no runoff allowed)

Total Leachate for Cell 1 Model = Run #1 Leachate + Run #2 Leachate

Cell 2 Model HELP Runs

- Run #3: Active Bottom of Cell 2, 2.5% slope bottom slope, 2% waste surface slope (with no runoff allowed)
- Run #4: Open Side slopes of Cell 2, 33.0% slope, bottom and surface (with no runoff allowed)
- Run #5: Closed Cell 1, 2.5% bottom slope, with 2 ft of alluvial soil covering the top lift of waste, 2% surface slope (with runoff allowed).

Total Leachate for Cell 2 Model = Run #3 Leachate + Run #4 Leachate + Run #5 Leachate

Figure 1-1 illustrates the component areas of the five HELP runs.

1.3 Storm Water Surge with Less Than One Lift of Waste in Place

The evaporation pond sizing will be based on annual water budgets with monthly time steps using the above-referenced leachate inputs. However, the leachate piping and pumping systems must be designed to handle a short-term storm surge event that may occur when there is little or no waste in place. The design storm for this event is the 25-year recurrence, 24-hour storm event, which is 1.73 in. (Sagendorf 1996). The Cell 2 catchment area (which is larger than Cell 1) is approximately 307,000 ft^2, resulting in a storm surge volume of approximately 354,000 gallons. Based on precedents from similar landfill designs, the pumping system must be designed to draw down this surge volume from an open cell in 72 hours or less, resulting in a required drawdown rate of 82 gpm. This leachate collection system design parameter is discussed in more detail in "Landfill Leachate Collection System Design Analysis," (EDF-ER-280).

1.4 Action Leakage Rate

In the event of a leak in the landfill liner, it is useful to know the worst flow that could be generated. The design of the ICDF is such that a leak in the primary liner directs leachate flow to the leachate detection sump. The Environmental Protection Agency (EPA) provides a recommended method for calculating the rate of leakage or Action Leakage Rate (ALR). This calculation is found in Section 4 of this EDF.

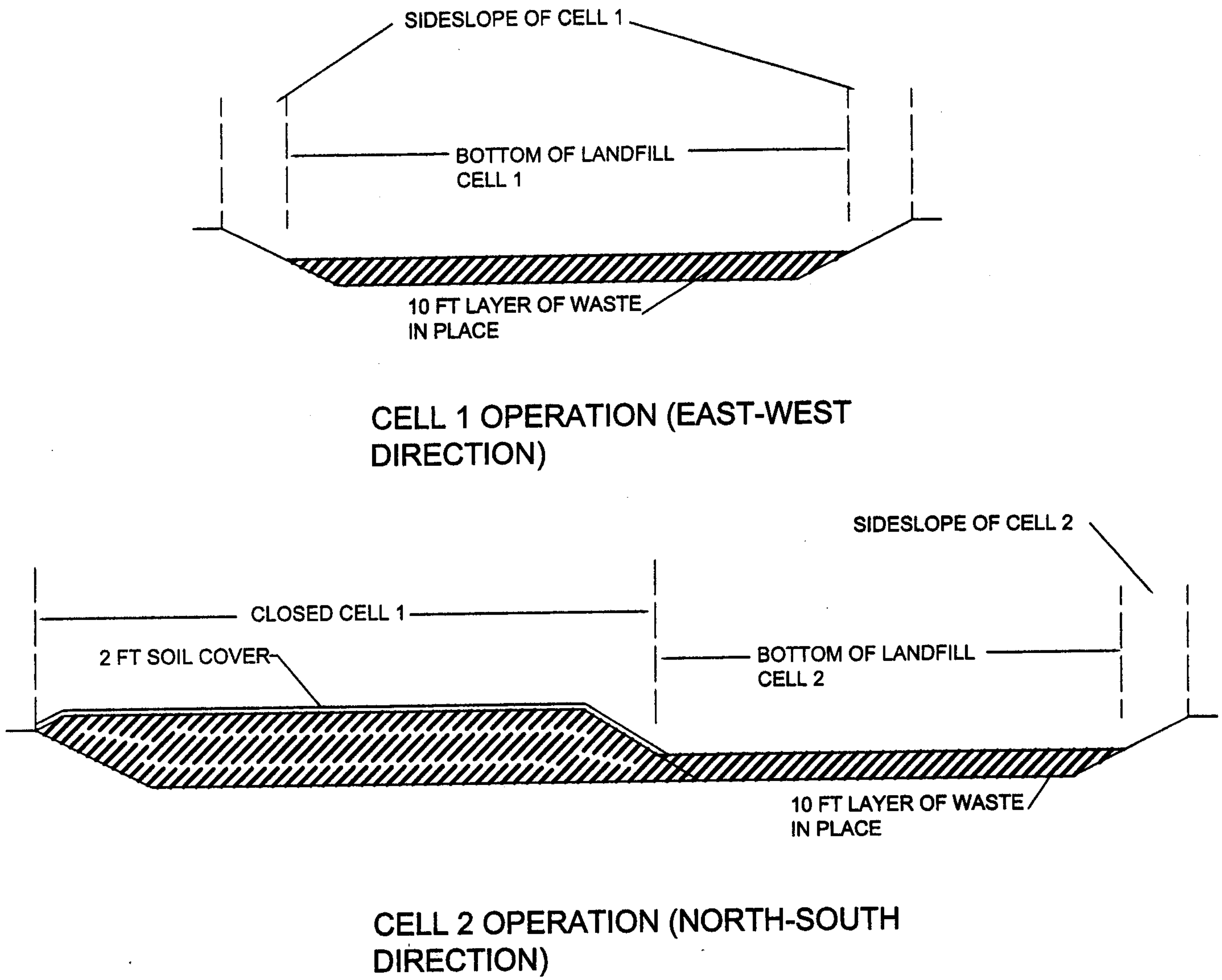

Figure 1-1. Schematic cross section of the ICDF demonstrating HELP model run areas.

2. HELP MODEL INPUT/DESIGN CRITERIA

Input to the HELP model consists of the following:

- Precipitation
- Moisture content temperature
- Solar radiation
- Altitude
- Waste characteristics
- Landfill dimensions
- Leachate path length
- Liner configuration.

A data set of precipitation, temperature, and solar radiation was derived from the period of record for use in this EDF and "Hydraulic Modeling of Final Cover," (EDF-ER-279). This data set contains daily precipitation for the wettest consecutive 10 years that have been recorded at the Central Facilities Area (CFA), shown in Figure 2-1. The data are documented in "UNSATH Infiltration Model Calibration at the Subsurface Disposal Area, Idaho National Engineering Laboratory," (Martian 1995).

Ten years were modeled in HELP using the data set. Complete results for the 10-year period are provided in Section 3.0.

2.1 Precipitation

Daily precipitation data have been recorded at the CFA since 1950. Measurements at other locations within the INEEL, such as the Test Area North (TAN), were also recorded. For the purpose of this study, only CFA precipitation data were used; the CFA averages were higher than averages computed using data from other local stations and, therefore, represent more conservative design criteria.

Precipitation data was derived from the NOAA records through 1999 for the NOAA weather station, "Idaho Falls 46 W", near Idaho Falls. This is the same weather station referenced as "CFA" (page 5, paragraph 3) in "Climatography of the Idaho National Engineering Laboratory, 2nd Edition, December 1989" (NOAA, December 1989).

Snow accumulation and melt is calculated in the HELP model in the following manner. When daily temperature is below 32 degrees in the synthetic model, the program stores precipitation on the surface as snow. Snowmelt is computed using a procedure based after the SNOW-17 routine of the National Weather Service Forecast System Snow Accumulation and Ablation Model. To compute the non-rain melt, air temperature is used as an index to energy exchange across the snow-air interface.

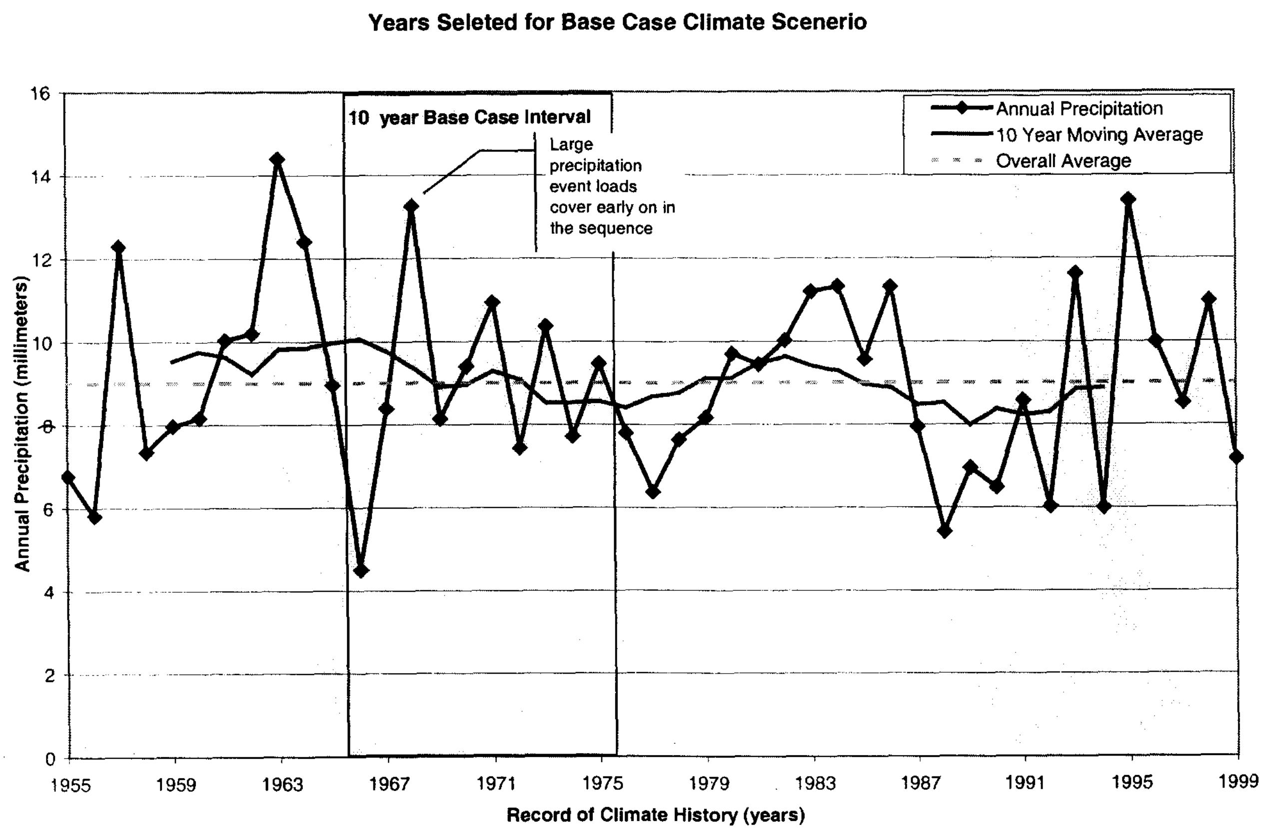

Figure 2-1. Precipitation data for CFA 1955-1999 and 10-year model period 1967-1976.

2.2 Dust Control

Application of water for dust control is typically performed by spraying down each load during active placement. For the ICDF, it was assumed that 5,000 gallons of water would be added to the landfill surface twice weekly during anticipated cell operating months—March through November. Water for dust control can vary widely depending on the nature of the incoming waste and conditions at the site during operation. An amount of 10,000 gallons/week is thought to be reasonable and conservative based on available information from other landfill sites in the area. Some examples of other landfill sites include the following:

- Kootenai County Farm Landfill in Kootenai County, Idaho (Subtitle D facility): This 35-acre facility uses leachate for interior roads and operations; in warm weather months, it can use up to 2,500 to 5,000 gallons per day (35,000 gallons/week). Note that this is a re-circulating landfill, so using leachate is to their advantage to reduce volume in their evaporation ponds.

- Northside Landfill in Spokane, Washington (Subtitle D facility): Dust suppression is used on exterior gravel access roads in varying amounts; none is used in the interior of the 13-acre landfill.

- Asotin County Regional Landfill in Asotin County, Washington (Subtitle D facility): Dust suppression is used on exterior gravel access roads in varying amounts, lignicite is used in the interior of the 15-acre landfill to control dust on the haul roads and tipping platform areas.

By choosing 5,000 gallons, a relatively conservative estimate is assured—the overall size is less than one-quarter of the Kootenai County Farm Landfill; one-quarter of the water usage would equal 8,750 gallons per week. The HELP model assumes 10,000 gallons/week (5,000 gallons twice weekly). It should be noted also that alternative dust control measures are currently being considered for the ICDF for haul roads and fill areas that are not actively receiving waste lifts.

For modeling purposes, it was assumed that the water would be dispersed over the landfill surface area in Cell 1 (an area of about 4 acres). This amount translates to 0.014 in./day during this time period, or around 5.1 in./year. The daily amount of 0.014 in./day was added to the daily precipitation input in HELP for analysis of the landfill bottom leachate flow generation. It should be noted here that the addition of 5.1 in. to the precipitation totals has the effect of increasing modeled precipitation for some years beyond an amount ever measured at CFA. The combined yearly total from maximum monthly precipitation at CFA was 14.4 in. (NOAA 1989).

2.3 Moisture Content of Incoming Waste

The incoming waste to ICDF is primarily soil from the surrounding INEEL facility. This soil is a well-graded granular soil consisting primarily of alluvial material. Data from the *Geotechnical Report for the Conceptual Design of the INEEL CERCLA Disposal Facility at Waste Area Group 3, Operable Unit 3-13* (DOE-ID 2000) for the granular alluvium was used to estimate input soil moisture data and water holding capacity for the waste materials to be placed in the landfill. From the geotechnical report, natural moisture content of the native alluvium is typically less than 5% and averages around 3%. The optimum moisture content of the material is around 7% for Standard Proctor compaction (ASTM D698). For modeling in HELP, a default soil value was chosen that most closely exhibits these properties. The HELP model offers 42 choices of soil/material each with unique parameters; Soil texture 5 was chosen for modeling (see Section 2.7 below for further discussion on waste layer). Once the soil texture type was chosen, it was necessary to consider the moisture of the incoming waste for the modeling. A value for soil moisture content was chosen based on field capacity, a parameter that expresses the total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity. Water in excess of the field capacity, will be released as leachate. By choosing a value near the field capacity, a reasonably conservative estimate of leachate is assumed. The rationale for using this value is that spraying the waste for dust control may increase the moisture content to near optimal; additionally, there is the case where waste enters the facility with greater than average moisture—during a wet period, for instance. By choosing a value of 13% (field capacity is 13.1—see Appendix A), the model assumes a larger than average contribution to leachate due to initial moisture content input.

2.4 Evapotranspiration

Daily temperature data from the NOAA records through 1999 for the NOAA weather station, "Idaho Falls 46 W", near Idaho Falls NOAA for Idaho, was used in the model. Evapotranspiration is computed by the HELP model based on temperature, solar radiation, average wind speed, and other parameters. Specific data inputs for the HELP program may be found in the HELP model output under "Evapotranspiration and Weather Data" in Appendix A.

2.5 Landfill Dimensions

Dimensions of the landfill including distances and areas were calculated using the 90% and 30% Draft Title I design drawings. Some assumptions were made in selecting the areas used in the HELP models: For the Cell 1 operation case, both the Cell 1 bottom area and the side slopes extended to the liner edge at the future Cell 2 interface (note that wastes would actually be held back from this interface about 15 ft for connection of the liner system in Cell 2 construction). For the Cell 2 operation case, the Cell 1 closed placed the boundary of the 2-ft-thick interim native soil cover over Cell 1, including the landfill bottom and three side slopes (north, east, and west) of the Cell. A side slope at the southern end of closed Cell 1 intersects the layer of waste in Cell 2. The following areas were calculated for the modeling scenarios:

1. Cell 1 Operation:

   a. Bottom of Cell 1 Landfill: Area = 194,300 ft^2 (4.5 acres), slope = 2.5%

   b. Cell 1 Side slopes: Area = 85,850 ft^2 (2.0 acres), slopes = 33.0% or 3:1 (H:V).

2. Cell 2 Operation:

   a. Bottom of Cell 2 Landfill: Area = 220,500 ft^2 (5.1 acres), slope 2.5%

   b. Cell 2 Side slopes: Area = 86,400 ft^2 (2.0 acres), slope = 33.0% or 3:1 (H:V)

   c. Cell 1 Closed: Area = 282,900 ft^2 (6.5 acres), slope = 2.5%

2.6 Maximum Head Using Mound Model and HELP

The maximum allowable head over the leachate liner for ICDF is 12 in. To ensure compliance with this specification, the head over the liner was examined using the Mound Model developed by EPA (EPA 1989). Results for the Mound Model were compared with those from HELP to further ensure compliance.

Calculations of maximum head using the Mound Model were performed for each of the five trial runs defined in Section 2.1, and may be found in Appendix B. The amount of leachate used in the Mound Model was determined using HELP, taking the maximum monthly average leachate from the 10-year trial period for each trial run and converting the amount (HELP reports inches) to ft^3/ft^2*min. Results for the Mound Model are shown in Section 3.1.

HELP and the Mound Model requires an input of maximum leachate path length or distance between collection pipes in the ICDF design. This length is defined as the maximum distance leachate travels to the low point in the specified landfill area. A distinction needs to be made regarding the low point in each HELP model. For HELP runs involving the landfill bottom (Run #1, Run #3, and Run #5), the lowest point for the landfill bottom was the sump area shown on the design drawings. For HELP runs involving side slopes (Runs #2 and #4), the low point was the toe of the side slope (intersection of side slope and the waste layer). The model uses the path length to compute head build-up over the liner. Placed at each of these "low points" will be drainage pipes from which the leachate will discharge from the drain layers (as will be described in more detail in "Landfill Leachate Collection System Design Analysis," [EDF-ER-280]).

The HELP model generates predicted maximum head over the liner based on a given leachate path length. This parameter is useful to examine the build-up of head over the liner; ensuring that build-up did not exceed the required maximum of 1 ft per performance specifications and applicable or relevant and appropriate requirements. If HELP predicts greater than 1 ft of head anywhere over the liner, it would be necessary to consider intermediate leachate drain pipes, and thus shorter leachate path lengths. Leachate path lengths for the HELP model runs are presented in Table 2-1. The resulting head build-up on the liner is presented in Section 3.

Table 2-1. Leachate path length based on preliminary leachate collection design and landfill design drawings.

Leachate Location	Maximum Length of Path
Cell 1 bottom	320 ft
Cell 1 side slopes	100 ft
Cell 1 closed	320 ft
Cell 2 bottom	520 ft
Cell 2 side slope	100 ft

2.7 Liner/Cover Considerations

The HELP model allows the user to specify various layers and layer properties for a given liner system. The liner design for the ICDF has the following layers, from top to bottom, for use in the model:

- A 3-ft-thick operations layer consisting of selected excavated alluvial soil with the same hydraulic properties as assumed for the waste soil
- A leachate collection layer consisting of 1-ft-thick drainage gravel enveloped with a non-woven geotextile
- A flexible membrane liner
- A 0.24-ft-thick geosynthetic clay liner (GCL)
- A geocomposite drainage layer
- A second flexible membrane liner
- A 3-ft compacted clay liner.

Appendix A contains the model output from HELP. Layers are numbered sequentially starting with the first layer in the stratum and continuing through to the bottom layer. For example, in Run #1, on page A-1, Layer 1 is the Waste Soil Layer. Properties for this layer are listed below the layer number and material texture type. Table 2-2 provides a summary for two of the HELP model runs.

The waste soil layer in the HELP output and associated properties are as follows: Run #1 page A-1 Layer 1, Run #3 page A-43 Layer 1, Run #5 page A-85 Layer 2. Note that Run #2 and Run #4 (side slopes) were modeled with no waste in place and Run #5 contains a 396-in. (30-ft) waste layer overlain by a 2-ft interim cover, representative of the closed condition. Closed condition here refers to the case where Cell 1 is full and the interim cap is in place and not the complete final closed state with a final cover. The final cover is discussed in other EDFs.

Parameter values for soil properties for layers used in the model other than the waste layer, were chosen based on the Geotechnical Report (DOE-ID 2000) and Design Specification SPC-1476 and the corresponding default soil, waste, and geosynthetic characteristics as presented in the HELP User's Guide for Version 3, Table 4. The layers are summarized below in Table 2-2.

Table 2-2. Profile and soil characteristics for input to the HELP model Run #1, Run #3.

Table 2-2. (continued).

Layer Number	Material Type	Layer Type[a]	Layer Thickness (in.)	Soil Texture Type[b]	Saturated Hydraulic Conductivity (cm/s)	Source for Parameter Selection[c]
1	Waste Soil Layer	1	120	5	1.00E-03	**A**
2	Operations Layer Soil	1	36	3	3.10E-03	**A**
3	Drainage Layer Gravel	2	12	21	3.00E-01	**B**
4	Flexible Membrane Liner	4	0.06	35	2.00E-12	**B**
5	Geosynthetic Clay Liner	3	0.24	17	3.00E-08	**B**
6	Geonet Drainage Layer	2	0.2	20	1.00E+01	**B**
7	Flexible Membrane Liner	4	0.06	35	3.00E-01	**B**
8	Soil Bentonite Liner	3	36	16	1.00E-06	**B**

a. HELP Layer types: 1 - vertical percolation; 2 - lateral drainage; 3 - barrier soil liner; 4 - geomembrane liner

b. HELP Soil-texture types and their characteristics are shown in HELP User's Guide for Version 3, Table 4

c. Sources for parameter selection:

A *Geotechnical Report for the Conceptual Design of the INEEL CERCLA Disposal Facility at Waste Area Group 3, Operable Unit 3-13* (DOE-ID 2000).

B SPC-1476 Technical Specifications (SPC-1476).

Two material layers that were characterized by existing site information from the Geotechnical Report include the Waste Soil Layer and the Operations Soil Layer. The Waste Soil Layer was assumed to be native alluvium. Of the 52 samples taken, those samples within the upper 15 ft of the surface were found to range from silty sand with gravel, USCS type SM, to well-graded sand and gravel, USCS type SW to GW. Appendix F of the Geotechnical Report, (DOE-ID 2000) provides the permeability for three soil samples. The reported hydraulic conductivity for the shallow and intermediate depths (up to ~15 ft) material is between 2.9×10^{-4} and 1.8×10^{-2} cm/sec. A Type 5 of the Default soil values in HELP, with a hydraulic conductivity (permeability) 1×10^{-3} cm/sec, was chosen from the list of default soil values as representative of a range of the reported actual range of hydraulic conductivity values.

The Operations Layer Soil consists of select native soils, those that exhibit qualities necessary for an operations layer, small percentage of fines, and good compaction. Because the native soil consists of type SM, to well-graded sand and gravel, a designation well-graded, or SW, is an appropriate choice. Type 3 soil texture was selected for the default values as most closely matching those parameters found in the operations layer, a sandy, well-graded soil.

The technical specifications identify material property requirements for the other layers of the cross-section including the following:

- Drainage Layer Gravel: The gravel layer will be defined in the Technical Specifications and corresponds to soil texture Type 21 in HELP, Gravel.

- Flexible Membrane Liners: Layers 4 and 7 in Table 2-1 are high-density polyethylene (HDPE) geomembrane liner, corresponding to HELP soil texture Type 35, HDPE Geomembrane.

- Geosynthetic Clay Liner: The GCL corresponds to HELP default texture Type 17, Bentonite Mat. The value for hydraulic conductivity in HELP, 3×10^{-9} cm/s, the value in SPC-1476 is given as 5×10^{-9}.

- Geonet Drainage Layer: Layer 6 is the drainage net and the corresponding HELP default texture is Type 20, drainage net.

- Soil Bentonite Liner: The soil bentonite liner corresponds to HELP default texture Type 17, Barrier Soil. The value for hydraulic conductivity in HELP, 1×10^{-6}cm/s is greater than that specified in SPC-1476 and therefore represents a more conservative choice for this layer; that is, more leachate may permeate the layer in the model than in actuality due to the higher permeability value used in the model.

3. HELP MODEL RESULTS

Table 3-1 presents modeled leachate production for the maximum year of the 10-year period modeled 1967 to 1976. The maximum year was taken as the maximum leachate produced from each trial run #1-5 (see Section 1.2 for breakdown of component trial runs) using the inputs described above. Table 3-2 presents the average of the modeled leachate production over the 10-year period modeled. HELP reports the totals for leachate on a monthly basis. Both the average and the highest year leachate production will be used in the design of the leachate evaporation pond, as described in "Evaporation Pond Sizing with Water Balance and Make-up Water Calculations," (EDF-ER-271).

HELP also reports peak daily values for leachate flow for the trial period. These reported values are not the same as the maximum monthly leachate flow from the maximum—the peak daily values represent the extreme maximum from a wet 10-year period. The peak values were found for Cell 1 and Cell 2 operation by adding the appropriate peak daily amounts reported from each trial run (see Section 1.2 for breakdown of component trial runs). Converted to gallons per minute the following peak daily flow values were found: 21.0 gpm for Cell 1 operation and 21.1 gpm for Cell 2 operation.

Table 3-1. Total leachate generation from HELP model—maximum year in 10-year period.

	Cell 1 Open			Cell 1 Closed, Cell 2 Open		
Month	Leachate Volume (ft^3)	Leachate Volume (gal)	Flow (gpm)	Leachate Volume (ft^3)	Leachate Volume (gal)	Flow (gpm)
January	4,798.4	35,892.2	0.8040	5,338.8	39,934.0	0.8946
February	3,810.0	28,499.0	0.7068	4,264.6	31,899.2	0.7912
March	3,706.1	27,721.7	0.6210	4,171.7	31,204.1	0.6990
April	3,708.2	27,737.4	0.6421	4,123.5	30,843.9	0.7140
May	7,607.8	56,906.1	1.2748	7,992.7	59,785.5	1.3393
June	26,191.4	195,911.3	4.5350	26,708.5	199,779.6	4.6245
July	7,952.9	59,487.3	1.3326	8,553.5	63,980.0	1.4332
August	18,083.2	135,262.5	3.0301	18,354.2	137,289.5	3.0755
September	7,750.0	57,969.7	1.3419	7,857.1	58,771.3	1.3604
October	9,041.5	67,630.3	1.5150	9,523.5	71,235.7	1.5958
November	9,843.9	73,632.7	1.7045	10,483.0	78,413.0	1.8151
December	6,581.5	49,229.6	1.1028	7,231.0	54,087.7	1.2116

Table 3-2. Total leachate generation from HELP model—average over 10-year period.

	Cell 1 Open			Cell 1 Closed, Cell 2 Open		
Month	Leachate Volume (ft^3)	Leachate Volume (gal)	Flow (gpm)	Leachate Volume (ft^3)	Leachate Volume (gal)	Flow (gpm)
January	3,186.7	23,836.6	0.5340	3,504.1	26,210.9	0.5872
February	2,425.8	18,144.9	0.4500	2,691.5	20,132.5	0.4993
March	2,334.7	17,463.9	0.3912	2,601.8	19,461.4	0.4360
April	3,004.8	22,475.8	0.5203	3,253.4	24,335.3	0.5633

Table 3-2. (continued).

	Cell 1 Open			Cell 1 Closed, Cell 2 Open		
Month	Leachate Volume (ft^3)	Leachate Volume (gal)	Flow (gpm)	Leachate Volume (ft^3)	Leachate Volume (gal)	Flow (gpm)
May	6,775.1	50,677.7	1.1353	7,010.1	52,435.5	1.1746
June	10,528.2	78,750.6	1.8229	10,840.7	81,088.3	1.8770
July	6,331.5	47,359.4	1.0609	6,664.0	49,846.4	1.1166
August	5,165.5	38,637.9	0.8655	5,370.6	40,172.3	0.8999
September	5,439.6	40,688.4	0.9419	5,589.5	41,809.2	0.9678
October	6,094.4	45,586.5	1.0212	6,331.9	47,362.9	1.0610
November	6,375.6	47,689.6	1.1039	6,670.4	49,894.7	1.1550
December	4,405.2	32,950.7	0.7381	4,720.9	35,312.1	0.7910

3.1 Maximum Head Results: HELP and Mound Model

HELP reports the average build-up of leachate on a yearly basis; HELP also reports a maximum build-up of leachate on the primary liner for the entire trial period of 10 years. To satisfy requirements of the performance specifications, it was necessary to look at the maximum head such that no leachate builds above the level of 1 ft. Results for the maximum build-up of leachate during the entire 10-year period over the landfill liner for Cell 1 operation and Cell 2 operation are shown on Table 3-3 for both the HELP model and the EPA Mound Model. Mound Model calculations are found in Appendix B.

Table 3-3. HELP model 10-year maximum head over liner for leachate path length based on preliminary leachate collection system design.

Leachate Location	Maximum Leachate Length of Path (ft)	Maximum Head using HELP(in.)	Maximum Head using Mound Model (in)
Cell 1 bottom	320	0.2	1.0
Cell 1 side slopes	100	0.0	0.2
Cell 1 closed	320	0.0	0.0
Cell 2 bottom	520	0.2	1.5
Cell 2 side slope	100	0.0	0.2

4. ACTION LEAKAGE RATE

The ALR is defined in the Final Rule 40 CFR Part 264.302, (EPA 1992b) as the "maximum design flow rate that the leak detection system...can remove without the fluid head on the bottom liner exceeding 1 ft." This calculation was performed to determine the ALR for the ICDF. EPA provides generic ALR values of 100 gallons/acre/day for landfills. Results for the ALR were compared to the generic values provided by EPA.

EPA provides a formula based on Darcy's Law for calculating action leakage flow capacity, assuming that the liquid originates from a single hole in the primary liner (EPA 1992b):

$$Q = k\tan(A)B \tag{1}$$

Where,

Q = flow rate in leak detection system (LDS)

K = hydraulic conductivity of drainage medium in LDS

H = head on secondary liner

A = slope of LDS

B = width of flow in LDS, perpendicular to flow direction.

The major uncertainty associated with this formula is determining the value of B, which is a complex function. Additional information is provided by EPA in a background document (EPA 1992a). By assuming that the shape of the wetted area downslope from the hole is parabolic, EPA rewrites equation 1 as:

$$Q = kD(2H-D) \tag{2}$$

Where,

D = thickness of drainage layer

Other parameters are the same as in equation (1).

The term kD is the transmissivity of the geocomposite drainage layer in the LDS. At the ICDF, this parameter will have a minimum value of 2×10^{-4} m^2/sec, per preliminary liner design specifications. The head on the secondary liner is defined as 1 ft per 40 CFR 264.302. A value of 5 millimeter (mm), or 200 mils was used in the equation based on preliminary design specifications SPC-1476 Specification 02373, Table 1 (SPC-1476).

4.1 Action Leakage Rate Results

Using equation (4b) and the assumed input parameters, the ALR for the ICDF landfill cell is 1,380 gallons per day. This value includes a FS of 2 in accordance with EPA guidelines (EPA 1992a). Details of the calculation are presented below. Using the generic value provided by EPA of 100 gal/acre/day, the ALR = 100* 14 acres or around 1,400 gallons per day, which agrees with the calculated value. This result forms the basis for the design of the LDS sump and pump.

ALR for ICDF:

$$Q = kD(2H-D) \qquad (3)$$

Where,

Q = flow rate in LDS

k = hydraulic conductivity of drainage medium in LDS

D = thickness of drainage layer in LDS

H = head on secondary liner.

At the ICDF:

$$kD = 2.00E\text{-}04\ m^2/sec \qquad (4)$$

Where,

D = 0.005 m

H = 0.3048 m

Therefore,

Q = 0.000121 m^3/sec

2,760 gallons/day

Apply Factor of Safety   two per EPA guidance

ALR   1,380 gallons/day.

5. REFERENCES

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